
Biomechanical effects on amusement ride passengers

Effets biomécaniques sur les passagers des manèges

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Published in Switzerland

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 254, *Safety of amusement rides and amusement devices*.

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Introduction

Most passenger-carrying devices, e.g. vehicles, transport systems, elevators, cableways, and other similar structures, are deliberately designed to minimize biomechanical effects on passengers. Amusement rides are different in that the biomechanical effects are deliberately introduced in order to amuse people through stimulation of their sensory system.

Thus, in addition to mechanical, electrical and other hazards, amusement rides could feature significant biomechanical hazards for passengers. Passengers being moved by amusement rides are subject to inertia forces. The magnitude, direction, duration of exposure to, and rate of change of, these forces could create risks that need to be minimized. The risks may be increased by the use of entertaining effects.

Design of the amusement ride in accordance with this Technical Specification, together with ISO 17842, minimizes any risks from these biomechanical effects.

When it is important for safety reasons, passenger weight, height, and age also need to be considered.

Moreover, amusement ride passengers can have different states of health or well-being during a ride cycle and there is a probability of injury not due to any amusement ride defect but owing to the individual health state of a passenger. When a designer, manufacturer or operator provides a warning before the ride entrance for guests, making them aware of ride use restrictions considering their state of health (see [Annex D](#)), this can limit legal liability for possible harm to passengers in poor health.

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Biomechanical effects on amusement ride passengers

1 Scope

This Technical Specification has been drawn up with the objective of ensuring the safety of amusement ride passengers, based on the international experience of manufacture and operation of such structures throughout the world gained over decades prior to its publication.

It enables the identification of potential hazards and classification of biomechanical effects, including information on recommended acceleration limits, rate of their onset and their duration, to ensure acceptable degrees of biomechanical risks at the stage of amusement ride design, as well as to take such risks into account during development of operational procedures and information on use limitations for amusement ride guests.

It gives recommendations regarding use limitations for amusement rides in accordance with the health condition and the well-being of passengers. It also specifies body dimensions of passengers 1,20 m to 2,0 m in height for motion risk analysis on amusement rides. These body dimensions can be taken into account when designing passenger containments and restraints.

It does not cover devices used in the circus, theatre or sports, or other devices intended for use only by specially trained people. Nevertheless, it can be used in the design of any similar structural or passenger-carrying device even if it does not explicitly mention the device.

This Technical Specification is not applicable to amusement rides put into operation before the date of its publication.

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2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 17842 (all parts)—¹⁾, *Safety of amusement rides and amusement devices*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1

amusement ride

equipment that is designed to entertain the passengers during motion, including biomechanical effects

3.2

biomechanical effects

effects of forces on passengers of amusement rides associated with their motion

3.3

degree of potential biomechanical risk

likelihood of causing harm as a result of biomechanical effects of different values considering the possible severity of consequences

1) To be published.

**3.4
entertaining effect**

psycho-emotional effect

action on the human sense organs associated with the use of visual effects, illumination, darkness, fire, water, wind, sounds, smells, etc. with the purpose of entertaining people

**3.5
fence**

structure designed to restrict or prevent movement across a boundary

**3.6
high potential biomechanical risk degree**

RB-1

potential of causing fatal harm to a passenger or passengers resulting from biomechanical effects

**3.7
low potential biomechanical risk degree**

RB-3

potential of causing harm with temporary disability of a passenger or passengers resulting from biomechanical effects.

**3.8
medium potential biomechanical risk degree**

RB-2

potential of causing severe harm to health of a passenger or passengers resulting from biomechanical effects

**3.9
motion risk envelope**

zones around the bodies of passengers carried by the amusement ride within the reach envelopes in which, if it is intruded by any structures or foreign obstacles, the passengers may be exposed to harm of varying degrees of severity

**3.10
negligible potential biomechanical risk degree**

RB-4

potential of causing harm without any form of disability to a passenger or passengers resulting from biomechanical effects

**3.11
passenger containment**

components (e.g. seating, foot wells, handrails, and passenger restraints) designed to prevent passengers from moving outside a predetermined area on a ride either as a result of biomechanical effects or the ride forces or the behaviour of the passenger

**3.12
rate of onset of acceleration**

value that characterizes the rate of acceleration growth during the given time interval (third derivative of movement in time)

**3.13
restraint**

system, device, or characteristic that is intended to inhibit or restrict the body movement and/or keep the body position to tolerate accelerations of the passenger(s) while on the amusement ride

**3.14
use limitation**

limitation for passengers with health deviations including but not limited to reasons related to their age, height or weight as well as for guests who are not feeling well to use an amusement ride safely

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4 Degrees of potential biomechanical risks for amusement rides

When people are being moved by an amusement ride, the respective potential risks of harm may be present depending on the potential fall height, values of velocity and accelerations, angle of the seat inclination or turnover. Therefore, measures to reduce or eliminate risks shall be taken with regard to the types and degrees of biomechanical effects acting on passengers. In order to analyse the risks and possible consequences of failures, it is important to take into account how people are exposed to biomechanical effects and the frequency of such exposure.

Biomechanical effects produced by amusement rides are not always suitable for people with health problems or who are simply not feeling well at the time, and therefore it is necessary to warn people of how extreme the amusement ride may be and of any use limitations.

Types of injuries depending on the severity of harm to the human body can include but are not limited to

- a) traumatic brain injury (TBI),
- b) vascular injury due to turning upside down,
- c) cardiac arrhythmia due to stress and/or accelerations action,
- d) severe injury of internal organs due to impact,
- e) injury of a musculoskeletal system when exposed to high accelerations, and
- f) loss of consciousness due to accelerations.

If the safety measures taken are not adequate, any biomechanical effects of an RB-1 value may cause catastrophic harm to health or life of people, those effects may, for example, include falling from the height of over 8 m; being hit against an obstacle at a speed of higher than 20 m/s; ejection of an unrestrained passenger out of a passenger unit; falling of an unrestrained passenger headlong out of a turned over passenger unit or seat from the height of more than 3 m.

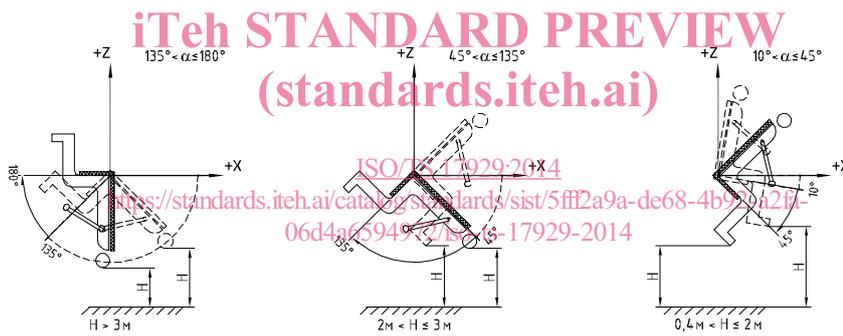
Similarly, any biomechanical effects of an RB-2 value may cause critical harm to health, including a severe injury or disability, and any biomechanical effects of an RB-3 value may cause harm to health such as temporary disorder. It should be noted that, if safety measures are insufficient and any unfavourable events or situations occur, increased biomechanical effects may result in high risk which will require risk analysis.

Identification of types and values of effects and degree of potential biomechanical risks shall be performed using [Table 1](#), [Figures 1 a\)](#), [1 b\)](#), and [1 c\)](#) illustrate inclination types of passenger seats.

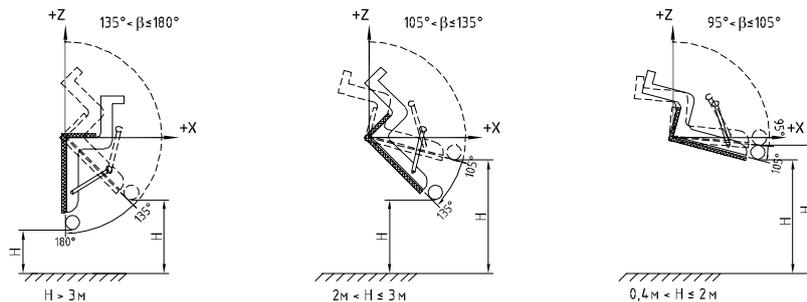
Table 1 — Types and values of effects to which passengers are exposed and degrees of potential biomechanical risks

Type of biomechanical effect	Notation	Degree of potential biomechanical risk			
		RB-1	RB-2	RB-3	RB-4
Lift to or drop from a relative height ^a	H, m	$H > 8$	$2 < H \leq 8$	$0,4 < H \leq 2$	$H \leq 0,4$
Travel at a relative velocity	$V, m/s$	$V > 20$	$10 < V \leq 20$	$3 < V \leq 10$	$V \leq 3$
Lift or drop in seat with inclination:	H, m	$H \geq 3$	$2 < H \leq 3$	$0,4 < H \leq 2$	$H < 0,4$
— forward inclination [Figure 1 a)]	$\alpha, \text{degrees}$	$135 < \alpha \leq 180$	$45 < \alpha \leq 135$	$10 < \alpha \leq 45$	
— backward inclination [Figure 1 b)]	$\beta, \text{degrees}$	$135 < \beta \leq 180$	$105 < \beta \leq 135$	$95 < \beta \leq 105$	
— sideward inclination [Figure 1 c)]	$\gamma, \text{degrees}$	$120 \leq \gamma \leq 180$	$60 \leq \gamma \leq 120$	$30 < \gamma \leq 60$	

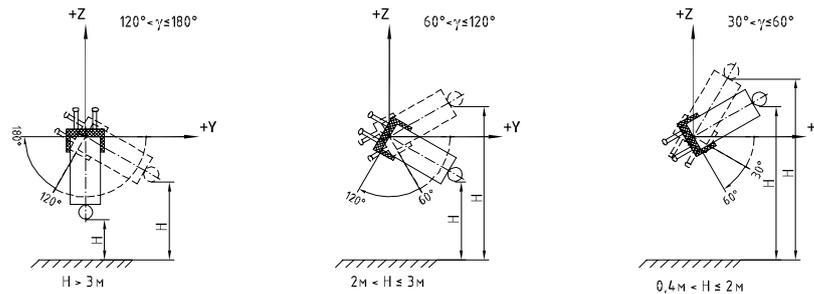
^a The degrees of biomechanical risks are based on the statistics regarding consequences of injuries to people when falling from height.



a) Forward inclination



b) Backward inclination



c) Sideward inclination

Figure 1 — Degrees of potential biomechanical risks depending on height and/or inclination for a seated unrestrained passenger

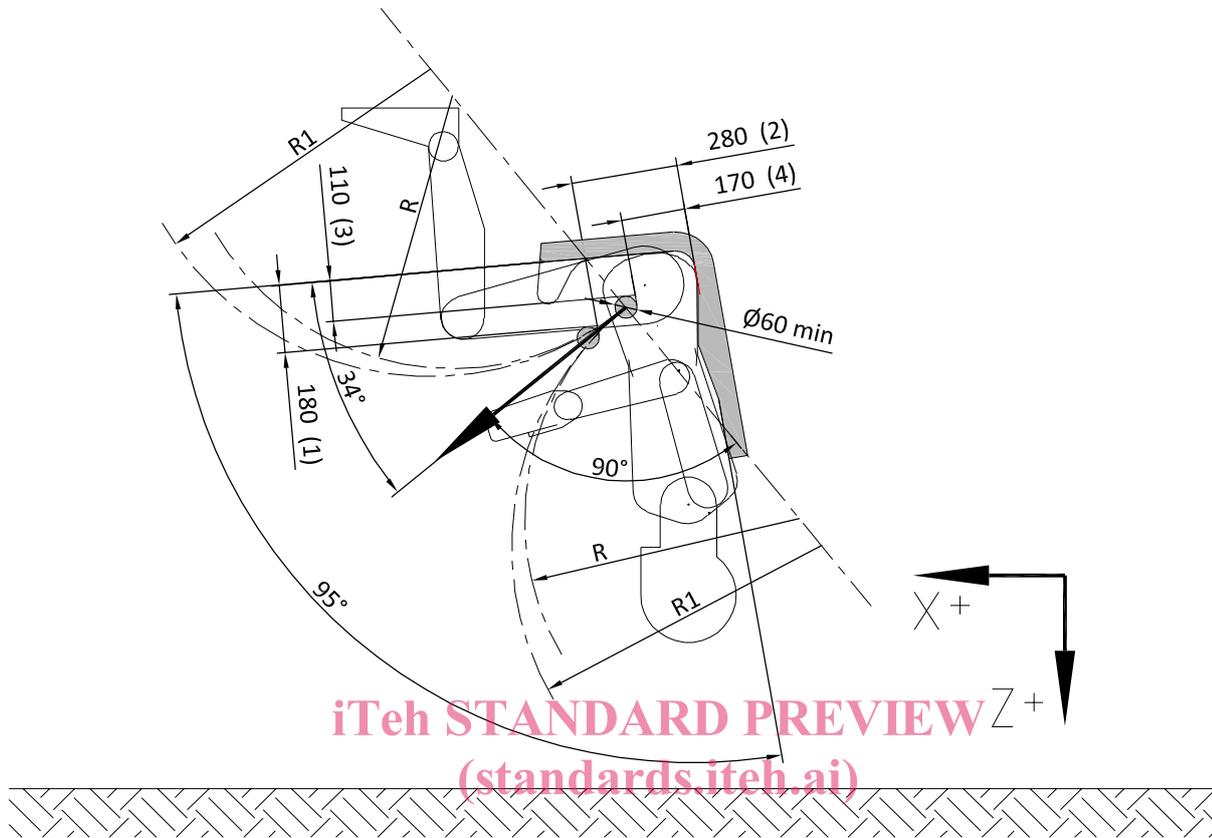
5 Measures for elimination or reduction of hazards due to biomechanical effects

Biomechanical risk analysis and risk classification for amusement rides concentrate the attention of those who make and maintain amusement rides on the elements and parameters most important for the safety of amusement rides.

Biomechanical risks arising from the types of effects listed below shall be eliminated or reduced by means of the following basic methods, in accordance with ISO 17842-1, and the necessity for redundancy depends on the risk analysis:

- when passengers are at a height of more than 2 m, reliable load-carrying structures and fences with due allowance for wind effects shall be provided as well as appropriate lifts and hoists;
- when passengers are being moved at a high speed (more than 3 m/s), appropriate containment devices shall be provided to prevent falling or potential ejection of passengers taking into account effects of inertia — measures shall be taken to remove obstacles that may cause harm getting into the relevant motion envelopes of passengers;
- when passengers are moved with high accelerations comparable with allowable limits for each axis, the passenger's body shall be secured with a restraint in order to ensure that accelerations are safely tolerated and to eliminate risk of passenger ejection due to acceleration (including under normal and emergency braking);
- when seats or passenger units are turned over and there is a probability of passengers falling out, appropriate passenger containment shall be provided.

Passenger containment may include restraints as part of the containment system. [Figure 2](#) provides an example of the geometry of the contact of a lap-bar type restraint with a passenger.



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Key

- (1) thigh clearance (the highest point of the thigh above the sitting surface) (measurement 27, Reference [8])
- (2) body depth, sitting – a horizontal distance between the seat back and anterior protrusion of the body (measurement 36, Reference [8])
- (3) thigh clearance for an anthropometric model of 1200 mm in height (scaling down of measurement 27 given in Reference [8])
- (4) horizontal distance between the seat back and anterior protrusion of the body for an anthropometric model of 1200 mm in height (scaling down of measurement 36 given in Reference [8])

Figure 2 — Example of the size and position of a restraint bar to hold passengers when turning upside down in emergency

A complete passenger containment system shall be designed and verified by ergonomic testing.

To accommodate a passenger in an upside down position, other passenger containment systems may be designed.

These provisions are applicable for passengers of 1,20 m to 2,0 m in height.

To take necessary design and organizational safety measures for minimising risks originated from amusement rides, the experience of the designers, manufacturers, and operators shall be in conformity with the complexity of an amusement ride and with the degree of its biomechanical hazard.

Elimination or reduction of high degree biomechanical risks shall be provided using the following safety measures:

- designing amusement rides in accordance with the ISO 17842-1 standard requirements;